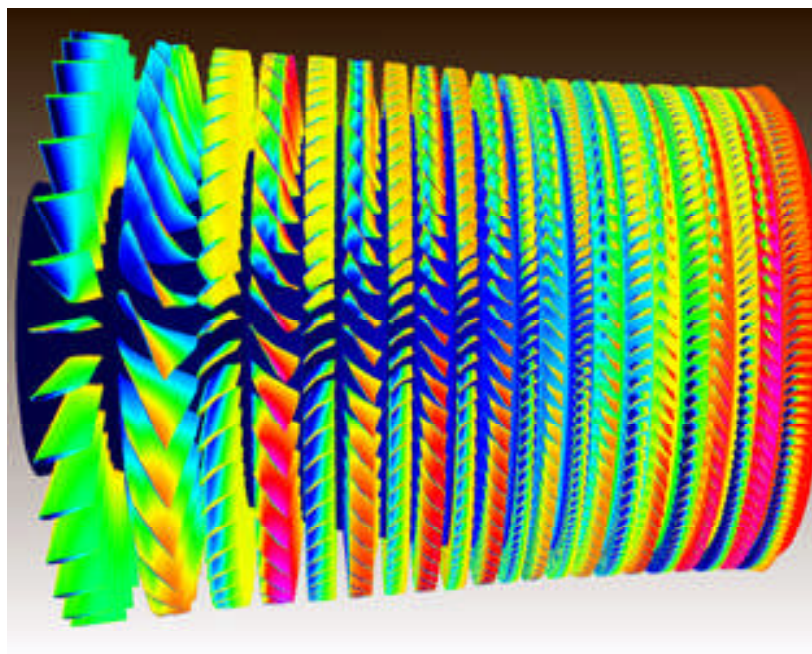


Flow of GE90 Turbofan Engine Simulated

The objective of this task was to create and validate a three-dimensional model of the GE90 turbofan engine (General Electric) using the APNASA (average passage) flow code. This was a joint effort between GE Aircraft Engines and the NASA Lewis Research Center. The goal was to perform an aerodynamic analysis of the engine primary flow path, in under 24 hours of CPU time, on a parallel distributed workstation system. Enhancements were made to the APNASA Navier-Stokes code to make it faster and more robust and to allow for the analysis of more arbitrary geometry. The resulting simulation exploited the use of parallel computations by using two levels of parallelism, with extremely high efficiency.

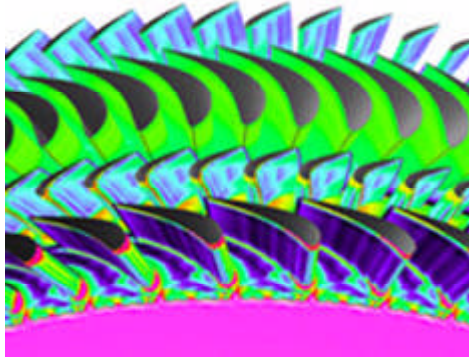
The primary flow path of the GE90 turbofan consists of a nacelle and inlet, 49 blade rows of turbomachinery, and an exhaust nozzle. Secondary flows entering and exiting the primary flow path-such as bleed, purge, and cooling flows-were modeled macroscopically as source terms to accurately simulate the engine. The information on these source terms came from detailed descriptions of the cooling flow and from thermodynamic cycle system simulations. These provided boundary condition data to the three-dimensional analysis. A simplified combustor was used to feed boundary conditions to the turbomachinery. Flow simulations of the fan, high-pressure compressor, and high- and low-pressure turbines were completed with the APNASA code.



GE90 high-pressure compressor surface pressures.

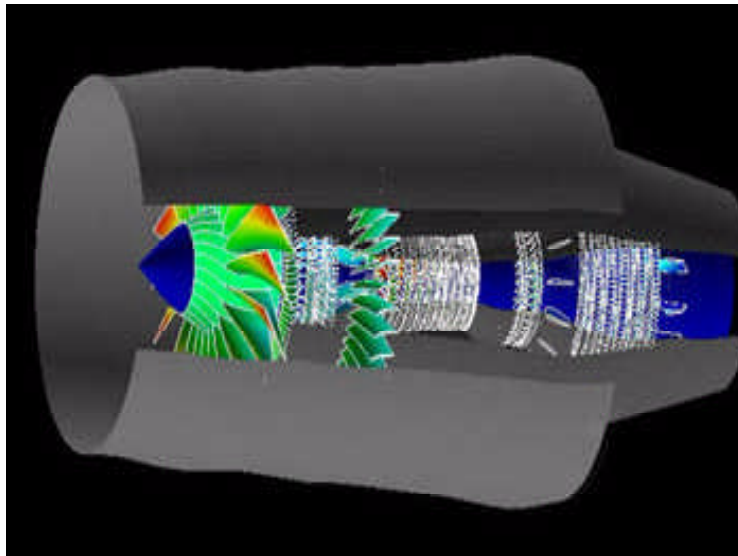
Two high-pressure compressors were modeled, the original and a new, improved design.

The APNASA flow simulation of the new geometry predicted a significant performance improvement over the baseline design. APNASA has been further validated by these rig tests. The 128-processor SGI Origin at the NASA Ames Research Center was used to simulate the compression system, which comprises 31 blade rows, in 38 hours of elapsed time. The computer simulation time to convergence on the 18-blade row, cooled, high- and low-pressure turbine simulation was 15 hours.



GE90 high-pressure cooled turbine flow simulation.

Because of its higher efficiency and reduced specific fuel consumption, the improved high-pressure compressor will significantly reduce the operating cost of the GE90 engine. The accurate predictive simulation capability of APNASA will increase design confidence in future versions of the baseline GE90 engine featuring higher levels of thrust. Increased design confidence will result in fewer test rigs and lower costs during development and certification.



Full GE90 turbofan engine flow simulation (with simple combustor).

All the major engine components have been simulated with APNASA for 49 blade rows (see the final figure). This high-fidelity simulation will be used by GE to evaluate modifications for future versions of the GE90 to reduce derivative engine development

time and cost. This work, which is a major element of the Numerical Propulsion System Simulation (NPSS), supports the High Performance Computing and Communication Program's (HPCCP) Grand Challenge milestone to "Demonstrate end-to-end reductions in cost and time to solution for aerospace propulsion design applications on heterogenous computing systems."

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